PROTOCOL FOR EQUIPMENT VERIFICATION TESTING FOR PHYSICAL CHEMICAL REMOVAL OF NITRATE FROM CONTAMINATED WATER SUPPLIES

DRAFT as of April 11, 1997

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Recommended by
the Steering Committee for the Verification of
Package Drinking Water Treatment Systems/Plants
on (insert date)

With support from
the U.S. Environmental Protection Agency
Environmental Technology Verification Program

INTERNET DOCUMENT INFORMATION FORM

A . Report Title: Protocol for Equipment Verification Testing: For Physical Chemical Removal of Nitrate From Contaminated Water Supplies

B. DATE Report Downloaded From the Internet 2/21 /98

C. Report's Point of Contact: (Name, Organization, Address, Office Symbol, & Ph #): U. S. Environmental Protection Agency
Las Vegas, Nevada

D. Currently Applicable Classification Level: Unclassified

E. Distribution Statement A: Approved for Public Release

F. The foregoing information was compiled and provided by:
DTIC-OCA, Initials: VJM **Preparation Date**: 2/21/98

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NSF INTERNATIONAL

Mission Statement:
NSF International (NSF) is an organization dedicated to public health safety and protection of the environment by developing standards, by providing education and by providing superior third-party conformity assessment services while representing the interest of all stakeholders.

NSF Purpose and Organization
NSF *International* (NSF) is an independent not-for-profit organization. For more than 52 years, NSF has been in the business of developing consensus standards that promote and protect public health and the environment and providing testing and certification services to ensure manufacturers and users alike that products meet those standards. Today, millions of products bear the NSF Name, Logo and/or Mark symbols upon which the public can rely for assurance that equipment and products meet strict public health and performance criteria and standards.

Limitations of use of NSF Documents
This protocol is subject to revision; contact NSF to confirm this revision is current. The testing against this protocol does not constitute an NSF Certification of the product tested.

U.S. ENVIRONMENTAL PROTECTION AGENCY

Throughout its history, the U.S. Environmental Protection Agency (EPA) has evaluated technologies to determine their effectiveness in preventing, controlling, and cleaning up pollution. EPA is now expanding these efforts by instituting a new program, the Environmental Technology Verification Program---or ETV---to verify the performance of a larger universe of innovative technical solutions to problems that threaten human health or the environment. ETV was created to substantially accelerate the entrance of new environmental technologies into the domestic and international marketplace. It supplies technology buyers and developers, consulting engineers, states, and U.S. EPA regions with high quality data on the performance of new technologies. This encourages more rapid availability of approaches to better protect the environment.

ETV's Package Drinking Water Treatment Systems Pilot Project:
Concern about drinking water safety has accelerated in recent years due to much publicized outbreaks of waterborne disease and information linking ingestion of high levels of regulated contaminants to cancer incidence. The U.S. EPA is authorized through the Safe Drinking Water Act to set numerical contaminant standards and treatment and monitoring requirements that will ensure the safety of public water supplies. However, small communities are often poorly equipped to comply with all of the requirements; less costly package treatment technologies may offer a solution. These package plants can be designed to deal with specific problems of a particular community; additionally, they may be installed on site more efficiently---requiring less start-up capital and time than traditionally constructed water treatment plants. The opportunity for the sales of such systems in other countries is also substantial.

Partnerships:
The U.S. EPA and NSF International (NSF) are cooperatively organizing and developing the ETV's' Package Drinking Water Treatment Systems Pilot Project to meet community and commercial needs. NSF and the Association of State Drinking Water Administrators have an understanding to assist each other in promoting and communicating the benefits and results of the project.

ORGANIZATION AND INTENDED USE OF PROTOCOL AND TEST PLANS

NSF encourages the user of this protocol to also read and understand the policies related to the verification and testing of package drinking water treatment systems and equipment.

The first Chapter of this document describes the Protocol required in all studies verifying the performance of equipment or systems removing nitrate from contaminated water supplies, the public health goal of the Protocol. The remaining chapters describe the additional requirements for equipment and systems using specific technologies to attain the goals and objectives of the Protocol: the removal of nitrate from contaminated water supplies.

A "Field Operations Document" (FOD) is necessary prior to the verification testing of a package drinking water treatment systems, plants and/or equipment. The FOD developer may need this protocol and the test plans herein and other NSF Protocols and Test Plans depending on the treatment technologies used in the unit processes or treatment train of the equipment or system More than one protocol and/or test plan may be necessary to address the equipment's capabilities in the treatment of drinking water and to complete an FOD.

TABLE OF CONTENTS

CHAPTER 1

PROTOCOL FOR EQUIPMENT VERIFICATION TESTING FOR PHYSICAL CHEMICAL REMOVAL OF NITRATE BY ION EXCHANGE AND MEMBRANE PROCESSES

REQUIREMENTS FOR ALL STUDIES

DRAFT 4/11/97

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

1.0 INTRODUCTION

This first chapter is the protocol for equipment verification testing for the physical chemical and biological removal of nitrate from contaminated water supplies. Specifically, this protocol discusses the information and procedures requested from equipment manufacturers who wish to have their package treatment plants verified and tested under the NSF/EPA verification testing program. In order to participate in the equipment verification process a Manufacturer Field Operations Document (FOD) using this study protocol and adhering to the requirements herein is necessary.

The contents of the Manufacturer FOD are described in this protocol document. The manufacturer will include only those items of information that pertain to his specific equipment and testing objectives. The descriptive material in this protocol represents the format and type of information which would be required for NSF/EPA verification testing. The Manufacturer FOD should not be viewed as a promotional document, but as a document which will transfer technical information about the equipment, the site of the testing and information regarding successful operation to those unfamiliar with the equipment and location of the test.

The testing of new technologies and materials which are unfamiliar to the NSF/EPA will not be discouraged. For example, resins or membranes or any other material or chemical which have not been tested under the ANSI/NSF Standard 61 protocol may be employed in the package plant. If so, these materials must be identified for review by NSF/EPA. The disclosure of the existence or use of proprietary or patented material and procedures should also be made in the Manufacturer FOD.

The final submission of the Manufacturer FOD shall:

- include the information requested in this protocol;
- conform to the format identified herein;
- and conform to the specific NSF International (NSF) Equipment Verification Testing Plan or Plans related to the statement or statements of capabilities that are to be verified.

The Manufacturer FOD may include more than one Testing Plan. For example, testing might be undertaken to verify performance of a package plant for both nitrate reduction and removal of disinfection byproduct precursors.

This protocol document is presented in two fonts. The non-italicized font provides background information that the Manufacturer may find useful in preparation of the Manufacturer FOD. *The italicized text indicates specific study protocol deliverables that are required of the Manufacturer and that must be incorporated in the Manufacturer FOD.*

The following glossary terms are presented here for subsequent reference in this protocol:

- Distribution System - A system of conduits by which a primary water supply is conveyed to consumers typically by a network of pipelines.

- EIR - An Environmental Impact Report which may be required to construct and operate a package treatment plant.

- Manufacturer - A business that assembles and/or sells package plant equipment and/or modular systems. The role of the manufacturer is to provide the package plant and/or modular system and technical support for the verification testing and study. The manufacturer is also responsible for providing assistance to the testing organization during operation and monitoring of the package plant or modular system during the verification testing and study.

- Manufacturer FOD - document of field testing operations and procedures. Document may be prepared by Manufacturer or by third party on behalf of Manufacturer and shall include the specific details of the experimental approach in the section titled Field Operations Procedures.

- Modular System - A functional assembly of components for use in a drinking water treatment system or packaged plant, each part of which provides a limited form of treatment of the feed water(s). Treated waters may be discharged to another packaged plant module or to the distribution system if the modular system includes the final step of treatment.

- Package Plant - A complete water treatment system including all components from connection to the feed water(s) through discharge to the distribution system. It is the entire system of water treatment plant equipment that is provided by the manufacturer. It shall include all equipment and materials which an owner/operator requires or is required by permits to install the system, operate it and discharge the final product into the distribution system, and todischarge waste into a waste disposal system. Any post treatment or blending facilities are included in the package plant. The package plant does not include any existing source water facilities, but it may or may not include waste discharge or containment facilities.

- NSF Equipment Verification Testing Plan - specific testing plan for each technology application, such as nitrate package plants or coagulation and filtration package plants. These plans are being developed by NSF to assist in development of Manufacturer FODs.

- Performance - Various plant operating factors described either quantitatively or qualitatively which characterize the plant's ability to meet the objectives of the treatment process.

- Permit. Any permit that is required to install and operate a package treatment plant such as conditional use permit, a construction permit, a treatment plant operation permit, a waste discharge permit or other such permit.

- Plant Operator - the person working for a small water system who is certified to operate a water treatment plant and who is responsible for operating package water treatment equipment to produce treated drinking water. This person also may collect samples, record data and attend to the daily operations of equipment throughout the testing periods.

- Reclaimed Water - Water that is a byproduct of the treatment process and is discharged as

a wastewater and is reused as irrigation water, cooling tower water or to satisfy similar water demands.

- Recycled Water - Water that is a byproduct of the treatment process that is reused in the process rather than being discharged as wastewater.

- Reliability - The ability of a package plant to meet the objectives of the treatment process over a long term on a consistent basis without excessive maintenance, operator time and down time.

- Responsible Water Agency or Owner/Operator - The person or agency (private or public) that owns the site and facilities where the package plant will be tested. It is likely that the owner will already be operating some water system facilities, such as a well, pump station, reservoir, treatment plant etc. at this site. This agency also represents a typical end user or purchaser of a package plant who has public water purveyor responsibilities under numerous local, State and Federal regulations.

- Study Protocol for Equipment Verification Testing- this document. Protocol shall be used for reference during Manufacturer participation in verification testing program;

- Testing Organization - an organization qualified to perform studies and testing of package plants or modular systems. The role of the testing organization is to ensure that there is skilled operation of a package plant during the intense periods of testing during the study and the tasks required by the Study Protocol for Equipment Verification Testing are performed. The Testing Organization is responsible for:

  - managing, evaluating, interpreting and reporting on the data produced by the verification testing and study;
  - providing logistical support, scheduling and coordinating the activities, e.g., establishing a communications network, of all participants in the verification testing and study;
  - advising the Manufacturer on feed water quality, waste disposal requirements and test site selection, such that locations selected for the verification testing and study have feed water quality consistent with the objectives of the Study Protocol for Equipment Verification Testing;
  - collecting and transporting analytical samples of water from water and wastewater streams and maintaining chain of custody documents;
  - collecting all field data on qualitative and quantitative evaluation factors.

- Verification - to establish the evidence on the range of performance of equipment and/or device under specific conditions following a predetermined study protocol.

- Waste, Waste Solids, Wastewater - The solid, liquid, or mixture of solid and liquid material that is produced by the water treatment processing equipment consisting of concentrated nitrate and other salt brines and rinse water and backwash water.

- Waste System - The portion of the package plant that contains, stores, transports, or pumps

the produced waste.

- Waste Disposal System - A facility, such as a sewer system, irrigated area,waste disposal site, ocean outfall, evaporation pond, deep well disposal system or other such system which will accept the waste produced by the package plant. This waste disposal system is not a part of the package plant.

1.1 Background

U.S. Environmental Protection Agency (EPA) has partnered with NSF, a nonprofit testing and certification organization, to verify performance of small package drinking water systems that serve small communities. It is expected that both the domestic and international markets for such systems are substantial. EPA and NSF have formed an oversight stakeholders group composedof buyers, sellers, and states (issuers of permits), to assist in formulating consensus testing protocols. A goal of verification testing is to enhance and facilitate the acceptance of small package drinking water treatment equipment by state drinking water regulatory engineers and consulting engineers while reducing the need for testing of equipment at each location where the equipment use is contemplated.

NSF will meet this goal by working with equipment Manufacturers and otheragencies in planning and conducting equipment verification testing, evaluating data generated by such testing and managing and disseminating information. The Manufacturer is expected to secure the appropriate resources to support their part of the equipment verification process, including provision of equipment and technical support.

The verification process established by EPA and NSF is intended to serve as a template for conducting water treatment verification tests that will generate high quality data for verification of equipment performance. The verification process is a model process that can help in moving small package drinking water equipment into routine use morequickly. The verification of an equipment's performance involves five sequential steps:

1. Development of a verification/Manufacturer FOD;
2. Execution of verification testing;
3. Data reduction, analysis, and reporting;
4. Performance, reliability and cost (labor, chemicals, energy) verification;
5. Report preparation and information transfer.

1.2 Objectives of Verification Testing

The verification testing objective(s) will be defined by the manufacturer. These specific objectives of the equipment verification testing will be different for each Manufacturer, depending upon the statement of capabilities of the specific equipment to be tested. The testing objectives developed by each Manufacturer shall be defined and described in detail in the Manufacturer FOD developed for each piece of equipment. The objectives of the equipment verification testing may include:

- Generate field data appropriate for verifying the performance of the equipment; generate field

data in support of meeting current or anticipated water quality regulations;

- Evaluate new advances in equipment and equipment design;
- Generate field data appropriate for verifying the performance of the equipment used in a specific environment such as a coastal region where ocean disposal is available;
- Generate field data appropriate for verifying the performance of the equipment operating within a specific range of untreated water quality;
- Generate field data appropriate for verifying the performance of the equipment used for specific modes of operation such as continuous or interrupted operation.

Multiple testing objectives may be included in the Manufacturer FOD. The development of specific objectives is discussed in Section 4.1. Water quality treatment objectives must also be defined in the FOD. The development of these objectives is discussed in Section 3.1.

An important aspect in the development of the verification testing is to describe the procedures that will be used to verify the statement of performance capabilities made for water treatment equipment. A verification testing plan document incorporates the QA/QC elements needed to provide data of appropriate quality sufficient to reach a defensible position regarding the equipment performance Verification testing conducted at a single site may not represent every environmental situation which may be acceptable for the equipment tested, but it will provide data of sufficient quality to make a judgment about the application of the equipment under conditions similar to those encountered in the verification testing.

It is important to note that verification of the equipment does not mean that the equipment is "certified" by NSF or EPA. Rather, it recognizes that the performance of the equipment has been determined and verified by these organizations.

1.3 Scope of Verification Process and Testing

This protocol outlines the verification process for equipment designed to achieve the physical chemical or biological removal of nitrate from contaminated water. The scope of this protocol includes Testing Plans for package plants employing ion exchange, reverse osmosis, electrodialysis, or biological processes as the primary process for treatment. The package plant may consist of a single process or a combination of these processes. The package plant may also consist of one or more of these processes combined with a waste treatment process, such as biological denitrification. This protocol is not an NSF or third-party consensus standard and it does not endorse the products or technology described herein. An overview of the equipment verification process and the elements are described in this protocol document.

1.4 Scope of the Manufacturer FOD

Specifically, the Manufacturer FOD shall include at least the following items:

- Roles and responsibilities of verification testing participants; (See Section 2.0)
- A brief statement of the objectives of the test plan;
- A brief statement of the water quality treatment objectives;
- Procedures governing verification testing activities such as equipment operation and process monitoring; sample collection, preservation, and analysis; and data collection and interpretation; (See Section 3.0)
- Experimental design of the Field Operations Procedures; (See Sections 4.0 and 5.0)
- Quality assurance (QA) and quality control (QC) procedures for conducting the verification testing and for assessing the quality of the data generated from the verification testing; (See Sections 6.0 and 7.0) and
- Health and safety measures relating to biohazard (if present),chemical, electrical, mechanical and other safety codes. (See Section 8.0)

1.5 General Content of Manufacturer FOD:

The remaining sections of this chapter discuss the type of information which is required in the manufacturer FOD. At the end of each section the italicized textual material will give the required outline for treating the subjects discussed in the related section followed by a statement of the responsibilities of the participants. For example, the following is the general outline for the manufacturer FOD:

The structure of the Manufacturer FOD must conform to the outline below: The required components of the Document shall be described in greater detail in the sections below.

- *TITLE PAGE*
- *FOREWORD*
- *TABLE OF CONTENTS -The Table of Contents for the Manufacturer FOD shall include the headings provided in this document although they may be modified as appropriate for a particular type of equipment to be tested.*
- *EXECUTIVE SUMMARY -The Executive Summary describes the contents of the Manufacturer FOD (not to exceed two pages). A general description of the equipment, the testing objectives, and the statement of water quality treatment objectives and capabilities which shall be verified during testing shall be included, as well as the testing locations, a schedule, and a list of participants.*
- *ABBREVIATIONS AND ACRONYMS - A list of the abbreviations and acronyms used in the Manufacturer FOD shall be provided*
- *EQUIPMENT VERIFICATION TESTING RESPONSIBILITIES (See Section 2, below.)*
- *EQUIPMENT CAPABILITIES AND DESCRIPTION (See Section 3, below.)*
- *EXPERIMENTAL DESIGN (See Section 4, below.)*
- *FIELD OPERATIONS PROCEDURES (See Section 5, below.)*
- *QUALITY ASSURANCE TESTING PLAN (See Section 6, below.)*
- *DATA MANAGEMENT AND ANALYSIS (See Section 7, below.)*
- *SAFETY PLAN (See Section 8, below.)*

Manufacturer Responsibilities:

Preparation of a Manufacturer FOD that includes the above information requested and conforms to the requirements stipulated in this protocol document described in the remaining sections o f Chapter 1, and the applicable NSF Equipment Verification Testing Plan or Plans.

2.0 EQUIPMENT VERIFICATION TESTING RESPONSIBILITIES

2.1 Verification Testing Organization and Participants

This verification testing program is being conducted by NSF International with participation of manufacturers, under the sponsorship of the EPA Office of Research andDevelopment, National Risk Management Research Laboratory, Water Supply and Water Resources Division (WSWRD) - Cincinnati, Ohio. The WSWRD and NSF jointly are administering the Equipment Verification Testing Program. The NSF's role is to provide technical and administrative leadership and support in conducting the testing.

The specific responsibilities of each participant are discussed in Section 2.6. The required content of the field operations Document and the Manufacturer Responsibilities are listed at the end of each section. In the development of a Manufacturer FOD, a table which includes the name, affiliation, and mailing address of each participant, a point of contact, their role, and telephone, fax and E-mail address shall be provided.

The following participants should be listed in the Participants Table:
NSF, WSWRD, Site Owner, Site Operator, Plant Operator, Field Testing Organization, and any other responsible parties.

2.2 Organization

The organizational structure for the verification testing showing lines of communication shall be provided by the Manufacturer.

2.3 Verification Testing Site Name and Location

This section discusses background information on the verification testing site(s), with emphasis on the quality of the feed water, which in most cases may be the source water at the site. The need for treatment should be demonstrated. The manufacturer must submit the name and address of the owner/operator of the proposed site and submit a letter of agreement from the owner/operator of the site to allow testing of the package plant at the site. The manufacturer should consider listing a site which would be typical of his intended market not only in terms of the feed water quality but also in terms of location and environmental conditions. For example, if a manufacturer's market is in mid-western agricultural regions, the water quality, climate, and waste disposal systems would be different than those found in temperate coastal regions. If the manufacturer wishes to demonstrate a membrane package plant, choice of a site with TDS water quality problems would be desirable. It is likely that the package plant would be tested at a well site owned and operated by a public water

agency or private water company. In most cases, the equipment may be demonstrated at more than one site. In all cases, the equipment should be tested under different feed water quality (or source water quality) and seasonal weather and extreme climate conditions within the range available at the site(s).

2.4 Site Characteristics

The Manufacturer FOD must include a description of the test site and the immediately surrounding environment. Information about the site should be provided to show that it is feasible to adequately test a package plant(s). This shall include a description of where the equipment will be located. If available, give the street address, City, State and Zip code. An area location map showing access from major streets and highways and a site layout drawing with equipment foot prints and dimensions would be helpful. The drawing should indicate the location of existing facilities, the source of the feed water and where the treated water will go and where the waste will be discharged. It should be specifically mentioned if the treated water will go to waste or if it will be introduced into an existing water supply. It is also important to point out if treated water will be blended with untreated water before it is sent to waste or distribution. If so, the blending facility must be a part of the package plant. Indicate if any facilities other than the package plant would be required such as additional buildings or trailers for sample collection and analyses, electrical power, concrete pads, drainage facilities, protective coverings etc. Consider the following questions:

- Will the package plant supply water on a continuous or interrupted basis?
- If the package plant is down, how will the demand be met?
- If the feed water is the source water for an existing water treatment plant, describe the raw water intake, the opportunity to obtain raw water without the addition of any chemicals as feed water to the package plant equipment being tested, the pattern of operation of the raw water pumping (is it continuous or intermittent), if source water available from a pressurized line or from a storage reservoir, and facilities for handling treated water and waste (i.e, residuals) from the testing program.
- Do facilities exist on the site for disposal of wastes? If so, is the capacity large enough to handle waste from the package plant. Or, will new waste disposal facilities be required? The package plant will be tested at its maximum sustainable treatment flow rate (gallons per minute).
- What is this value and demonstrate it is compatible with the water supply and demand at the site?
- Will the operation of the test facility be compatible with the existing uses of the site and the surrounding land uses?
- Is it located in a residential area where neighbors may complain? If so, how will this be handled?
- Are any construction or conditional use permits required? Is a permit required to operate the package plant?
- Is a waste discharge permit required?
- What will be the ultimate method of waste disposal?
- Has the manufacturer consulted with the following: The owner/operator, the water agency, the local or State health organization, the waste discharge agency, local emergency officials (regarding safe fire flows), responsible health agencies who have jurisdiction?

- Have alternative sites been considered?
- Why was this site chosen in preference to other sites?
- Environmental documentation such as an EIR or environmental impact assessment relative to the proposed package plant testing should also be submitted or an explanation of why such environmental documentation may or may not be required.

Content of Manufacturer Field Operations Document Regarding Equipment Verification Testing Responsibilities:

The Manufacturer, in consultation with NSF as the technical lead , shall be responsible for including the following elements in the Manufacturer FOD:

- *Definition of the roles and responsibilities of appropriate verification testing participants*
- *A table which includes the name, affiliation, and mailing address of e ach participant, a point of contact, their role, and telephone, fax and E-mail address.*
- *Organization of operational and analytical support*
- *List of the site name(s) and location(s). Describe the site and the surroundings. Use location maps and provide other material discussed above.*
- *Description of the test site(s), the site characteristics and identification of where th e equipment shall be located (use foot print dr awings) and other pertinent material discussed above. Describe existing facilities on the site, how they will be used. List any permits and environmental documentation required. Provide other material discussed above.*

Manufacturer Responsibilities:

- *Provision of complete, field-ready equipment for verification testing;*
- *Provision of logistical, and technical support, as required. Remove equip ment and any discarded items from the site after termination of the test program.*
- *Provision of technical assistance to the site owner/operator and the qualified testin g organization during operation and monitoring of t he equipment undergoing verification testing as discussed above.*

3.0 EQUIPMENT CAPABILITIES AND DESCRIPTION

3.1 Equipment Capabilities, Water Quality Objectives

The manufacturer's FOD must state the treated water quality objectives. This objective must include the following:

1. The nitrate levels in blended water must be 80 percent of the MCL or less at all times.

2. Any secondary standard for any other constituent must not be exceeded at any time.
3. Any other objective the manufacturer wishes to include.

The Manufacturer must identify the type of feed water to be treated, the contaminant(s) to be treated for and the water quality objectives to be achieved in the statement of performance capabilities of the equipment to be evaluated in the verification testing. Statements should also be made regarding the applications of the equipment, what advantages it provides over existing equipment and the known limitations of the equipment. The statement of performance capabilities must be specific and be verifiable by a statistical analysis of the data. Examples of satisfactory statements of performance capabilities would be:

"This ion exchange package plant is capable of treating water contaminated with nitrate up to 100 mg NO_3/L by producing water with a nitrate level equal to or less than 35 mg NO_3/L in the treated water samples."

"This membrane package plant is capable of treating water having the following composition: TDS = 1200 mg/L (with sulfates = 300 mg/L or greater) and containing nitrate having a level of up to 100 mg NO_3/L and will produce water with a TDS level equal to 150 mg/L and a nitrate level equal to or less than 35 mg NO_3/L in the treated water samples."

Note in the above statement for membrane package plants, the sulfate level must also be stated.

A statement of performance capabilities such as: "This package plant will provide lower nitrate levels than required by the Safe Drinking Water Act on a consistent and dependable basis," would not be acceptable.

The statement of performance capabilities may also indicate the range of water quality with which the equipment can be challenged while successfully treating the feed water. Statements of performance capabilities that are too easily met may not be of interest to the potential user, while performance capabilities that are overstated may not be achievable or credible. The statement of performance capabilities forms the basis of the entire equipment verification testing and must be chosen appropriately. Therefore, the design of the ManufacturerFOD shall include a sufficient range of feed water quality to permit verification of the statement of performance capabilities. The water quality treatment objectives will differ from the verification testing objectives discussed in the next section.

3.2 Equipment Description

Description of the equipment for the verification testing program shall be provided by the Manufacturer. Data plates shall be permanent and securely attached to each production unit. The data plate shall be easy to read in English or the language of the intended user, located on the equipment where it is readily accessible. Open/closed indicators shall be clearly visible on al automatic valves as well as direction of flow arrows on all piping. Other information required is :

a. Equipment Name
b. Model #
c. Manufacturer's name and address

d. Electrical requirements - volts, amps, and Hertz
e. Serial Number
f. Warning and Caution statements in legible and easily discernible print size
g. Capacity or output rate (if applicable)
h. Any proprietary features should be described

Content of Manufacturer Field Operations Document Regarding Equipment Capabilities and Description:

The Manufacturer shall be responsible for including the following elements in the Manufacture r FOD:

- *A statement of the water quality objectives to be achieved by the equipment.*
- *Description of the equipment to be demonstrated. This shall include:*
- *1. Brief introduction and discussi on of the engineering and scientific concepts on which the water treatment equipment is based;*
- *2. Description of the treatment train and each unit process included in the package plant;*
- *3. Brief description of the physical construction/components of the equipment. Includ e general environmental requirements and limitations, weight, transportability, ruggedness, power and other consumables needed, etc.*
- *4. Statement of typical rates of consumption of chemicals, a description of the physical and chemical nature of wastes, and rates of waste production concentrates, residues, etc.).*
- *Definition of the performance range of the equipment.*
- *Operation and maintenance manual will be supplied for the equipment. Include a flo w diagram, piping and instrumentation diag ram, location of sampling points and flow meters, and a description of a typical start up, operation and shut down procedure. Indicate th e functioning of alarms and shut down alarms. Indica te plant adjustments required. All valves and controls and similar components are to be clearly marked on the equipment and s o identified in the flow diagram.*
- *Identification of any special licensing requirements associated with the operation of th e equipment.*
- *Description of the applications of the equipment and the removal capabilities of th e treatment system relative to existing equipment. Provide comparisons in such areas as : treatment capabilities, requirements for chemicals and materials, po wer, labor requirements, suitability for process monitoring and operation from remote locations, ability to b e managed by part-time operators.*

- *Discussion of the known limitations of the equipment. Include such it ems as the range of feed water quality suitable for treatment with the equipment, the upper limits for concentrations of regulated contaminants that can be removed to concentrations below the MCL, level of operator skill required to successfully use the equipment.*

4.0 EXPERIMENTAL DESIGN

This section discusses the objectives of the verification testing, factors that must be considered to meet the performance objectives, and the statistical and other means that the NSF should use to evaluate the results of the verification testing.

4.1 Objectives of Experimental Testing

The testing program must have well defined objectives. The Manufacturer FOD will include a statement of the verification testing objectives to evaluate equipment in one or more of the following areas: (1) performance relative to manufacturer's stated range of equipment capabilities; 2) how well it performs relative to the requirements of the Safe Drinking Water Act and any other specific or anticipated water quality regulation; 3) how well it performs relative to the performance recommendations for water filtration processes in the Partnership for Safe Water; 4) the impacts of variations in feed water quality (specifically variations in TDS, chloride, sulfate, nitrate and alkalinity are important) on its performance; 5) the logistical, human, and economic resources necessary to operate the equipment; 6) the reliability, ruggedness, cost, range of usefulness, safety and ease of operation and maintenance; 7) how much (or how little) waste is produced by the treatment process; and 8) the cost of treatment.

Although the manufacturer is encouraged to include all parameters listed below in the Manufacturers FOD, the Manufacturer shall be responsible for selection of the qualitative and quantitative parameters which must be evaluated to meet the water quality treatment objectives and the verification testing objectives. A list of parameters is listed below and in NSF test plans that are appropriate for most equipment. For example, if equipment is only intended for removal of nitrate, there would be no need to conduct testing to evaluate the removal of TDS. The manufacturer will state the verification testing objective that is appropriate for his equipment. For example, the Manufacturer may wish to focus on wastewater production and thus formulate his stated objective to include this factor.

4.2 Equipment Characteristics or Factors to be Tested

This section discusses factors that shall be considered in the design and implementation of the verification testing. These factors will be evaluated either quantitatively or qualitatively during the verification testing. The factors can include such items as: ease of operation, ease of maintenance, degree of operator attention required, operator labor (man-hours) required, response of equipment and treatment process to changes in feed water quality, electrical power requirements, system reliability features including redundancy of components, feed flow requirements, discharge requirements, spatial requirements for the equipment (footprint), unit processes included in treatment

train, and chemical inventories needed.

4.2.1 Qualitative Factors

Some factors, while important, are difficult or impossible to test or quantify. Important factors that cannot easily be quantified are the modular nature of the equipment, the safety of the equipment toward operators or spectators, the portability of equipment, and the logistical requirements necessary for using it. Aesthetics, security and compatibility with surrounding land use are important qualitative factors. For example, a plant located in a residential area should not appear out of place and it should be protected from and should not attract vandalism.

Maintenance operations such as ease/difficulty of membrane or resin cleaning and replacement should be discussed although these operations may not be carried out during the test procedure. The NSF would also require to know what labor would be required to terminate the tests and remove the package plant from the site.

Typical qualitative factors to be discussed are listed below, and others may be added. The Manufacturer FOD shall discuss those factors that are appropriate to the test equipment and the test site.

- Reliability or susceptibility to environmental conditions
- Equipment safety. Point out any feature or device which could harm the operator if malfunctions or mishandling occurred, such as chemical handling, high pressures discharges, unexpected noises, sudden pressure loss or build up.
- The need for any safety devices (e.g. fire extinguishers, air packs) or clothing which are required such as special shoes or safety glasses.
- Effect of operator experience on results. Discuss the level of experience that an operator should have to successfully achieve reliable and safe operation. Mention if special training would be required such as handling acids, leaks or spills.
- Special equipment required for moving or lifting heavy parts or materials.
- Aesthetics and security.
- Compatibility with surrounding land use.
- Health and safety features
- Alarms and set points
- Placement of instrumentation and monitoring devices for convenient operator reading, inspection and replacement.

4.2.2 Quantitative Factors

Many factors in this verification testing can be quantified by various means. Some can be measured and controlled while others such as chemical market prices cannot be controlled but can be measured. Typical quantitative factors to be considered are listed below, and others may be added. The Manufacturer FOD shall list and give estimates of these factors and describe how they can be measured during the field operation of the package plant or the test equipment. These factors will be also be field tested, measured and verified by the Testing

Organization during the testing and verification procedure.

4.2.3 Quantitative Factors: Definitions

The following definitions apply to the discussion of quantitative factors:

Financing Cost - The cost to finance the purchase of the package plant based on the rates of inflation, borrowed capital, and amortization period. To standardize cost calculations, these factors will be set by the NSF/EPA.

Untreated Water - The raw water which is delivered or available at the site for treatment by the package plant for nitrate removal.

Treated Water - The water stream that has passed through treatment (and post treatment) and is available from the package plant either for direct injection into a distribution system or for blending with untreated water before injection into the water supply system.

Blended Water - A mixture of treated and untreated water that is suitable for injection into the distribution system. This is the same as the distributed water.

Percent Blend - The percent of treated water that is in the blend. Thus a 75 percent blend will refer to water composed of 75 percent treated and 25 percent untreated water. A 100 percent blended water is equal to treated water.

Maximum Distribution Flow Rate - The maximum flow rate (gallons per minute) of blended (distributed) water which the package plant can cause to be injected into the distribution mains on a continuously operating basis with a nitrate level at or below 80 percent of the MCL.

Maximum Treatment Flow Rate - The maximum flow rate (gallons per minute) of treated water which the package plant can produce on a continuously operating basis while maintaining the Maximum Distribution Flow Rate.

Plant Factor - A factor used in computing water treatment cost. It is the fraction of total time the plant operates or is projected to operate during its period of amortization. NSF will determine this factor to standardize cost computations.

Percent Waste - 100 x the ratio of the annual wastewater production to the annual amount of treated water production.

4.2.4 Quantitative Cost Factors

All cost data must be quantified for verification testing. Cost will be expressed in two ways: (1) as cents per 1000 gallons for operating costs and amortized capital costs, and (2) as annual costs for operating expenses and capital costs. Also, wherever it is possible in a

discussion of cost it is useful to designate whether it is "O and M ","operating", "maintenance" "capital" or "total" for clarification. To standardize cost computations, a plant factor of 50 percent will be used to determine the annual production of the plant. The basis of the costs will be production of distributed water at the Maximum Distribution Flow Rate delivered at a pressure of 60 pounds to accommodate distribution system pressure. The total cost of all cost items will be estimated by the manufacturer for the duration of the testing period. The following first cost items may be estimated in the Manufacturers FOD:

- Capital costs of the package plant.
- Financing Cost.
- Delivery and transportation charges.
- Capital costs of any auxiliary equipment or facilities.
- Installation, start up, and checkout cost.

The following operation and maintenance cost items may be estimated in the Manufacturers FOD:

- Operating cost of power to operate the plant computed from the cost per kWhr.
- Operating costs of power to boost pressure for distribution.
- Operating cost of chemicals computed from costs as delivered by local suppliers.
- Replacement cost of resin and/or membranes.
- Cost of operator labor computed from direct and indirect labor costs.
- Cost of replacement parts. (List items)
- Cost of maintenance. (List items)
- Cost of service calls by equipment representatives.
- Capital and operating cost of waste disposal. (In cents/1000 gal of blended water).

4.2.5 Quantitative Plant Performance Factors

Significant quantitative factors relating to plant performance (other than the special water quality parameters discussed in the next section) must be included in the Manufacturer's FOD. These parameters relate to the daily and annual quantities of various streams and discharges and their flow rates. These performance factors must be estimated in the FOD and will be verified during the testing and verification program. Instrumentation such as flow meters, pressure gauges, conductivity meters, sampling taps, etc. must be provided as integral parts of the package plant. A diagram should be provided to illustrate where and how the factor can be measured and verified. If a multi vessel ion exchange plant is tested, the instrumentation should be located so the parameters can be checked for each vessel.

The following plant performance factors may be measured.

- Flow rate (gpm), electrical conductivity (e.c.), and pressure of treated water during normal treatment.
- Flow rate (gpm),e.c., and pressure of brine stream(s) during production.
- Flow rate (gpm), e.c., and pressure of backwash water during backwash.
- Flow rate (gpm), e.c., and pressure of rinse water during rinse.

- Daily amount of water treated (gallons) and delivered to distribution system.
- Daily amount of backwash water used.
- Daily amount of rinse water used.
- Daily amount of wastewater produced.
- Daily amount of make up water for brine maker.
- Daily amount of saturated brine used for regeneration and amount used per regeneration.
- e.c. and quantity of total wastewater produced.
- Percent of treated water in delivered water.

In nitrate treatment, it is very helpful to evaluate **overall plant performance and efficiency factors** which will indicate the amount of chemical added to the environment or the overall chemical costs associated with the treatment process. For example in ion exchange, sodium chloride must be purchased, transported and disposed. For a reverse osmosis plant, sulfuric acid must be added for pH adjustment and waste brines are produced. Indices of efficiency can include the following:

- Chemical equivalents of a specific chemical (e.g. salt or sulfuric acid) required by the process to remove one chemical equivalent of nitrate.

- Chemical equivalents of salt materials disposed in wastewater or brine reject by the process for removal of one chemical equivalent of nitrate.

- Operating cost to remove one pound of nitrate.

- Amount of wastewater produced by the process to remove one pound of nitrate.

4.2.6 Quantitative Factors: Plant Health, Safety and Reliability

Health, safety and reliability features are significant in package plant operation and verification testing. The safety features treated here refer to those items which protect the water supply and hence the drinking water public from unintended contamination. (Other types of safety features for on site plant personnel protection are treated in Section 8). The cost effectiveness of treating water diminishes rapidly if waste products and chemicals cause dangerous contamination because of poorly designed and/or operated equipment. In the rush and concern to eliminate the primary contaminant at a low capital cost, the focus on the importance of these safety features is easily lost. Primary dependence must be placed on the reliability and quality of the equipment designer, manufacturer, and operator. It is very likely that these features will be a primary interest of health officials who must review plant designs and issue operating permits. The field testing personnel should be aware of these sources of contamination and may need to devise means to check for acceptable operation.

The FOD must describe (1) the safety features that have been designedinto the package plant, (2) what contamination problem this feature is used to address, and (3) how the features can be field tested.

In nitrate treatment, the problem areas of concern are:

(1) Sudden loss of pressure in a distribution system being fed by a package plant can occur either by accident or by intention during distribution maintenance procedures. Pressure loss coupled with other equipment failures could be catastrophic unless reliable safety features are activated. Any mechanical device presents an opportunity for failure such as valve failures due to various mechanical causes including wear. Some valves close at slow rates or are improperly seated upon closure. Failure to properly close can provide pathways for wastes and brines to unintentionally enter the treated water supply. Treatment equipment pressure vessels, manifolds and piping often serve two purposes at different times: to contain both treated water and wastewater. Such an arrangement constitutes a direct cross connection in the event of isolation valve failure. Connections to distributed water mains for make up water, rinse water etc. present an opportunity for back siphoning of chemicals and waste into the distribution system.

(2) An ion exchange bed should not be operated too long or beyond its capacity to adsorb nitrate. The result is not only lack of nitrate adsorption but also a phenomenon called "dumping" can occur where much of the previously adsorbed nitrate is dumped back into the treated water supply.

(3) An ion exchange bed, after being regenerated with brine, vessels and piping should be rinsed thoroughly of the waste salt before being put back into service. If not properly rinsed, excessive TDS and salt could be discharged into the treated water.

(4) Introduction of waste rinse water or waste backwash water into the process stream or treated stream is also a potential source of contamination.

In proper plant design and operation, the above areas of concern will be carefully considered, although increased cost for safety features and extra use of rinse water and production of more wastewater may result.

As each package plant will have a different piping design and operating procedure, the location and operation of safety devices can only be generally described in this protocol document.

A simple procedure can be implemented to check for trouble spots in the event of loss of pressure in the distribution system. Use a flow diagram showing sensors and valves as reference and ask questions regarding any one valve, such as:

1. If the valve is normally closed during step 1 (e.g. during treatment) in the treatment process, could contamination result if the valve remained open? (e.g. a valve in a make up supply line and a chemical supply tank.)

2. If the valve is normally closed during step 2 (e.g. cleaning or rinsing), could contamination result if the valve remained open? (e.g. a valve to the treated water line)

Examples of other operation steps can be resin or membrane cleaning, standby, brine making, rinsing, etc. Each valve, whether normally opened or closed, can be so addressed during each different step of the treatment process. The same queries can be made assuming sudden loss of water pressure in the distribution line.

The following devices, piping and valve arrangements have been used to reduce unintentional contamination in specific cases.

1. Simple air gaps. The gaps should be frequently inspected for obstructions.
2. Sensors for shut down or warning alarms. High nitrate and TDS alarms are effective to detect contamination after it has occurred.
3. Back flow preventors, check valves and double check valves allow flow in only one direction. Addition of manually operated valves allow periodic testing by the operator.
5. Block and bleed valve arrangements. This arrangement consists of two automatically operated isolation valves in series with a third automatic valve between the two to act as a bleed valve. Flow from the bleed valve is a visual indication of failure of the blocking valves.

4.2.7 Cross Connection Control References and Guidelines

It is likely that each state will have adopted regulations covering the requirements for using cross connection prevention devices. Although the manufacturer's package plant will be tested in a given state (or states) it would be to his advantage to adopt measures which would apply to all states to give the broadest market for the package plant equipment. Useful publications are available from individual state and local health agencies such as "**Guidance Manual For Cross Connection Control Programs**" Published by the State of California, Department of Health Services, Sept 1988, Public Water Supply Branch. Other sources of information on this subject can be obtained from literature and certification training courses given by local plumbing unions. For example, "**A Course Of Instruction For Certification In Cross-Connection Prevention**" Fresno Area Plumbers, Pipe and Refrigeration Fitters JATC. **The Foundation for Cross Connection Control and Hydraulic Research** at the University of Southern California, Los Angeles, is another resource of information (213/749 2032).

The FOD must describe (1) the safety features that have been designed into the package plant, (2) what contamination problem this feature will address, and (3) the recommended field testing procedure and frequency.

4.3 Water Quality Considerations

Water treatment equipment is used to treat water and change the quality of feed water (or raw water) so it meets the requirements of the Safe Drinking Water Act, amendments to the Safe Drinking Water Act, and the proposed Groundwater Disinfection Rule. In addition, the treated water should be aesthetically pleasing and palatable. The experimental design shall be developed so the relevant questions about water treatment equipment capabilities can be answered.

Equipment Manufacturers should recognize that it is highly unlikely that any single process employed within a package plant can successfully treat any conceivable feed water containing all of the regulated contaminants and produce a treated water that meets the quality requirements for every regulated contaminant. Although multiple processes could be placed in a treatment train to accomplish such a goal, for most public water systems such comprehensive treatment capability is generally not needed and would not be cost effective.

The package plant is typically designed to treat only specific contaminants within a defined range of untreated water quality. Therefore, nitrate treatment is the subject of this protocol. It is, however, possible to broaden the applicability of treatment in the case of nitrate removal processes. In certain cases, water quality improvements regarding other constituents such as hardness, sodium, TDS, chloride, sulfate etc may also be desirable. The manufacturer can use auxiliary ion exchange treatment or membrane processes to reduce these constituents as well as the nitrate which is the constituent of primary concern. The manufacturer should state the range of water qualities and contamination that the equipment can successfully treat and the range of contaminantsor water quality problems that can be addressed. Manufacturers should carefully consider the capabilities and limitations of their equipment and prepare Manufacturer FODs that challenge their equipment sufficiently to enable the verification testing to provide a broad market for their products, while recognizing the limitations of the equipment and not subjecting it to testing for contaminant removal when the outcome is known in advance to be failure and the testing would be fruitless. The NSF Equipment Verification Testing Plans shall be used as the basis for the specific Manufacturer FODs.

4.3.1 Feed Water Quality

One of the key aspects related to water treatment equipment performance verification is the range of feed water quality that can be treated successfully, resulting in treated water quality that meets water quality goals or regulatory requirements. The FODpreparer should consider the influence of feed water quality on the quality of treated waters produced by the package plant, such that product waters meet the water quality goals or regulatory requirements. They should also consider the impact of various water quality parameters on the cost of the treatment process and the quality and quantity of the waste produced. As the range of feed water quality that can be treated by the equipment becomes broader, the potential market for treatment equipment with verified performance capabilities will also increase. The Manufacturer shall specify in the FOD the specific water quality parameters to be monitored in the Verification Testing Program. Also, the recommended operating range of these parameters should be stated The following feed water quality characteristics are important in nitrate treatment using ion exchange and membrane processes.

- A general mineral analysis including nitrate, nitrite, chloride, sulfate, bicarbonate, carbonate, pH, TDS, hardness, barium, silica, and all other major cations and anions.
- turbidity, particle concentration.
- temperature, with temperatures near freezing having potential for the most difficult treatment conditions.
- dissolved organic carbon (DOC), total organic carbon (TOC), or UV-254 absorbance.
- biological dissolved organic carbon (BDOC) or assimilable organic carbon (AOC).

- color.
- density (concentration) of microorganisms (bacteria).
- iron and manganese.
- presence of algae, particularly filter clogging algae.

One of the questions often asked by regulatory engineers in approval of package water treatment equipment is "Has it been shown to work on the water where you propose to put it?" By providing treatment capability covering a large range of water qualities the verification testing is more likely to provide an affirmative answer to that question.

4.3.2 Treated Water Quality

Treated water quality is the most significant measurement to be made in the testing program. If a Manufacturer states that water treatment equipment can be used to treat water to meet specified regulatory requirements, the verification testing must provide data that support such a statement of capabilities.

For nitrate treatment processes the manufacturer must provide a statement of capabilities to provide nitrate levels as specified in the SDWA and the state counterparts. In addition, the manufacturer may wish to make a statement about performance capabilities of the equipment for removal of other regulated contaminants under the SDWA.

Furthermore, some water treatment equipment can be used to meet aesthetic goals that are not included as regulatory requirements of the Safe Drinking Water Act. Water quality considerations that go beyond regulatory requirements and may be important for some small systems include:

- color, taste and odor
- total dissolved solids
- iron and manganese

Finally, other water quality parameters are useful for assessing equipment performance These may include:

- particle count or concentration
- heterotrophic plate count bacteria (HPC)
- BDOC or AOC

Other water quality considerations must also be made. Any treatment process which removes a contaminant also changes the composition of other constituents. For example in ion exchange nitrate is removed, sulfate and alkalinity are also removed and chloride is added; in a membrane process, nitrate is removed as well as other substances. The removal of these materials may produce a water quality incompatible with an existing distribution system These items must be addressed in the test plan.

4.3.3 Wastewater Characteristics, Quality and Quantity

The quality and quantity of wastewater produced by the package treatment plant is a very important consideration in testing the performance and acceptability of the plant. In many cases these factors can be the major determining considerations in the choice of treatment. In the case of an ion exchange plant treating for nitrate, the waste brine, although small in quantity, will be high in dissolved salts such as sodium chloride, bicarbonate, sulfate and nitrate. The waste discharge regulator or agency which accepts the waste will need to know the exact composition and quantity of waste before accepting it for discharge. Many wastes are discharged into a local sewer line, which, in turn transfers waste to a wastewater treatment facility. Often, the high TDS may impact the process of waste treatment or disposal. Some assessment of this impact should be done by the manufacturer. Often the wastewater treatment agency will charge a fee for accepting the waste into their system. If the nitrate treatment process is reverse osmosis, the wastewater will also contain high TDS as well as be high in volume. The agency accepting the waste must be assured that his facilities are adequate for accepting the waste.

In either case, the Manufacturer's FOD should contain the chemical composition and quantities of the various types of waste produced by the test plant. The methods of waste discharge and disposal should be listed and discussions and requirements of local wastewater disposal agencies should be documented in the FOD.

4.4 Recording Water Quality Data

For all nitrate removal tests, data should be maintained on the quality parameters listed in Sections 4.3.1 and 4.3.2 above and any other data required by the plant operating and waste discharge permitting agencies as described in Section 4.3.3. The frequency for each parameter will vary with nitrate measurements being the most frequent. The procedures and sampling requirements shall be provided in detail in the Verification Testing Plan. The following items of information shall also be maintained for each experiment:

- Type of chemical addition, dose and chemical combination, where applicable (e.g., salt, acid, chlorine, scale inhibitor, etc.);
- Water type (raw water, pretreated feed water, product water, waste water);
- Experimental run number (e.g. 1st run, 2nd run, 3rd run, etc.).

The manufacturer must provide labeled sampling taps and locations on the equipment to allow either manual or automatic sampling. The manufacturer must also provide a diagram showing where each labeled sample tap is located and the parameter which can be sampled at that location.

4.5 Instrumentation For Plant Control and Monitoring

The membrane and ion exchange equipment used for nitrate treatment are mechanical in nature and allow the use of probes and instrumentation to monitor or control the plant operation. The

manufacturers FOD should contain a description of these controls, their function and accuracy. The following are examples.

4.5.1 Nitrate Measurements

Under the SDWA, at no time should the nitrate in the distributed (blended) water exceed the MCL value. Frequent manual analysis of grab samples or automatic nitrate monitoring is required to assess the performance of nitrate removal plants. Monitoring this parameter in both the feed, treated and blended water is very informative of plant performance. Measurement of nitrate on a once or twice per day basis is not sufficient to detect rapidly changing values which can occur. It is well known that nitrate levels can change from minute to minute in water supplied by an intermittently operated pump. Likewise, whenever an ion exchange vessel undergoes a regeneration cycle, potential for high nitrates exists. Some vessels are regenerated five or more times per day. These potential fluctuations demand frequent manual or automatic monitoring. (Note: For reliability, plant control of the of the amount of water treated by each vessel before a regeneration must be done by reliable flow meters to measure a set point batch value and signal either to the operator or a control system to start the regeneration. Automatic plant control must not be based on nitrate measurements because of their rapidly changing nature).

Similarly, if membrane processes are used, nitrate variations can also occur as driving pressure or current flows change.

4.5.2 Electrical Conductivity Measurements

Electrical conductivity measurements (e.c.) can be an indicator of plant performance and can be measured and recorded on a continuous basis. If ion exchange is the process, this parameter will indicate if excessive salts from improperly operating equipment has contaminated the water supply. The excessive salts in the water supply should not exceed the secondary standards for chloride, sulfate and TDS and should be as close to the feed water electrical conductivity as possible. If a membrane process is used, the electrical conductivity of the product water will be less than that of the feed water and will be an indication of properly functioning equipment. The manufacturer's FOD should indicate the range of conductivities to be expected in the various streams.

4.6 Verification Testing Schedule

Verification testing activities include equipment set-up, start up and initial operation, verification operation, sampling and analysis, maintenance procedures and plant shut down. Initial operations are intended to be conducted so Manufacturers can test their equipment and be sure it is functioning as intended. If feed water (or source water) quality influences operation and performance of equipment being tested, the initial operations period serves as the shake-down period for determining appropriate operating parameters.

For nitrate treatment equipment, specific care must be taken during the start up procedure to disinfect equipment and media. Both ion exchange resins and membrane materials are sensitive to oxidants and disinfectants. The manufacturer should provide a procedure to ensure proper disinfection of his

equipment for the start up procedure and for subsequent occasions if required.

The timing for verification testing shall be designated on the basis of four annual testing episodes in order to cover a range of water quality conditions and ambient temperatures experienced in an annual period. For example, climatic changes between rainy and dry seasons or local agricultural practices may produce substantial variability in feed water nitrate and other water quality parameters. The timing for verification testing should include cold weather operations because of seasonal water quality variations and because of the impact of cold temperatures on mechanical devices, filtration and membrane devices.

- cold temperatures (1° to 5°C) can have an adverse affect on some water treatment processes due to the increase in water viscosity at cold temperatures. Cold temperature considerations may be particularly important for membrane filtration applications;

- water flows treated by many types of package watertreatment equipment are so great (80 to 100 liters/minute, or greater) that use of mechanical refrigeration to attain temperatures of 1° to 5°C would be prohibitively expensive;

- cold temperatures have an adverse effects on mechanical pumps, chemical feed pumps, compressors and automatically operated valves.

Verification testing with operations for which data are collected and used to verify performance would be done after initial operations are completed. The verification entity is to be notified of the date when verification testing is scheduled to begin.

Content of Manufacturer Field Operations Document Regarding Experimental Design:

The Manufacturer shall be responsible for including the following elements in the Manufacturer FOD:

- *Statement of the verification testing objectives.*

- *Identification and discussion of the water treatment problem or problems that the equipment is designed to address, how the equipment will solve the problem, and who would be the potential users of the equipment.*

- *Identification of the range of key water quality parameters, given in applicable NSF Testing Plans, which the equipment is intended to address and for which the equipment is applicable.*

- *Identification of the key parameters of treated water quality that shall be used for evaluation of equipment performance. Parameters of significance for treated water quality were listed above in Section 4, and in applicable NSF Testing Plans.*

- *Identification of the key qualitative parameters that shall be used for evaluation of equipment performance. Parameters of significance for treated water quality were listed above in Section 4, and in applicable NSF Testing Plans.*

- *Identification of the key quantitative parameters that shall be used for evaluation of equipment performance. Parameters of significance for treated water quality were listed above in Section 4, and in applicable NSF Testing Plans.*

- *Identification, description and testing procedures for safety components designed to prevent back flow, cross connections, or any unintended contamination of treated water.*

- *Detailed outline of the verification testing schedule, with regard to annual testing periods that will cover an appropriate range of annual climatic conditions, (i.e., different temperature conditions, seasonal differences between rainy and dry conditions).*

5.0 FIELD OPERATIONS PROCEDURES

5.1 Equipment Operations and Design

The NSF Verification Testing Plan specifies procedures that shall be used to ensure the accurate documentation of both water quality and equipment performance. Careful adherence to these procedures will result in definition of verifiable performance of equipment. (Note that this protocol may be associated with a number of different NSF Equipment Verification Testing Plans for different types of physical removal process equipment.)

Operation and design aspects of water treatment process equipment often provide a basis for approval or permitting by state regulatory engineers and can be used to pinpoint specific areas of concern related to operation of the equipment. Specific operation and design aspects to be included in the Manufacturer FOD are provided in detail, in the Manufacturer Responsibilities section below.

5.2 Selection of Analytical Laboratory and Field Testing Organization

To assess the performance of the equipment, the water quality attained using the equipment shall be determined by on-site analysis or by an NSF-qualified analytical laboratory, by a field operations and testing organization or by a combination of both. The Manufacturer shall use an NSF-qualified testing organization (laboratory or engineering company). The NSF may provide a list of qualified testing organizations from which Manufacturers can select for submission of analytical samples. For field operations, the Manufacturer shall employ an NSF-qualified field testing organization. These organizations may include engineering consulting firms, universities, or other qualified scientific organizations with experience operating pilot plant equipment.

In addition to NSF qualification, the analytical laboratories selected must also be certified for analysis of water samples for Safe Drinking Water Act compliance by one or more states having Safe Drinking Water Act primacy. Furthermore, the selected analytical laboratory must be certified by the State in which the verification testing is being performed. Because of the variability of acceptance of laboratories from state to state, use of an analytical laboratory certified in a large number of states is recommended. Laboratories approved for sample analysis for the EPA's Information Collection Rule would have nationally recognized capabilities. Analytical results from the laboratory are to be provided directly to the NSF to maintain data integrity.

The manufacturer and the testing organization will also need to cooperate with the water agency who accepts water for distribution within their system. Water analyses start up, monitoring and operational procedures must be performed in accordance with the regulatory permits required to operate the plant equipment. Periodic reports must be submitted to the regulating agencies according to permit requirements. *The manufacturer's FOD must designate who will be responsible for the plant operation and their qualifications and verify acceptance of the operator by the other participating members.*

5.3 Communications, Documentation, Logistics, and Equipment

NSF shall communicate regularly with the verification testing participants to coordinate all field activities associated with this verification testing and to resolve any logistical, technical, or QA issues that may arise as the verification testing progresses. The successful implementation of the verification testing will require detailed coordination and constant communication between all verification testing participants.

All Manufacturer/NSF field activities shall be thoroughly documented. Field documentation shall include field logbooks, photographs, field data sheets, and chain-of-custody forms. The qualified testing organization shall be responsible for maintaining all field documentation. Field notes shall be kept in a bound logbook. Each page shall be sequentially numbered and labeled with the project name and number. Field logbooks shall be used to record all water treatment equipment operating data. Completed pages shall be signed and dated by the individual responsible for the entries. Errors shall have one line drawn through them and this line shall be initialed and dated.

All photographs shall be logged in the field logbook. These entries shall include the time, date, direction, subject of the photograph, and the identity of the photographer. Any deviations from the approved final Manufacturer FOD shall be thoroughly documented in the field logbook and provided to the NSF.

Original field sheets and chain-of-custody forms shall accompany all samples shipped to the analytical laboratory. Copies of field sheets and chain-of-custody forms for all samples shall be provided to the NSF.

5.4 Initial Operations

Initial operations will allow equipment Manufacturers to refine their operating procedures and to make operation adjustments as needed to successfully treat the feed water. Information generated through this period of operation may be used to revise the Manufacturer FOD, if necessary. A failure at this point in the verification testing could indicate a lack of capability of the process equipment and the verification testing might be canceled.

5.5 Equipment Operation and Water Quality Sampling for Verification Testing

The qualified testing organization shall supervise equipment operation and water quality sampling and analysis during the verification phase of testing, using the procedures described below. The NSF

should oversee or audit these activities. All field activities shall conform with requirements provided in the Manufacturer FOD that was developed and approved for the verification testing being conducted.

If unanticipated or unusual situations are encountered that may alter the plans for equipment operation, water quality sampling, or data quality, the situation must be discussed with the NSF technical lead. Any deviations from the approved final Manufacturer FOD shall be thoroughly documented.

During routine operation of water treatment equipment, the total number of hours during which the equipment was operated each day shall be documented as well as the time required by the operator to perform various tasks. The qualified Testing Organization will record and verify the number of hours each day spent by the operator of the treatment plant and provide a description of the daily tasks performed by the operator of the treatment equipment.

Content of Manufacturer Field Operations Document Regarding Field Operations Procedures:

The Manufacturer shall be responsible for including the following elements in the Manufacture r FOD:

- *A table summary of the proposed time schedule for operating and testing,*
- *Field operating procedures for the equipment and performance testing, based upon the NS F Equipment Verification Testing Plan with listing of operating parameters, ranges for feed water quality, and the sampling and analysis strategy.*

Manufacturer Responsibilities:

- *Provision of all equipment needed for field work associated with this verification testing;*
- *Provision of a complete list of all equipment to be used in the v erification testing. A table format is suggested;*
- *Provision of field operating procedures.*

6.0 QUALITY ASSURANCE PROJECT PLAN (QAPP)

The QAPP for this verification testing specifies procedures that shall be used to ensure data quality and integrity. Careful adherence to these procedures will ensure that data generated from the verification testing will provide sound analytical results that can serve as the basis for performance verification.

6.1 Purpose and Scope

The primary purpose of this section is to outline steps that shall be taken by operators of the equipment and by the analytical laboratory to ensure that data resulting from this verification testing is of known quality and that a sufficient number of critical measurements are taken.

6.2 Quality Assurance Responsibilities

The Manufacturer project manager is responsible for coordinating the preparation of the QAPP for this verification testing and for its approval by the NSF. The qualified testing organization project manager, with oversight from NSF, should ensure that the QAPP is implemented during all verification testing activities.

The entire Manufacturer FOD including the QAPP must be approved by the Manufacturer and the NSF before the verification testing can proceed. The NSF must review and either approve the QAPP or provide reasons for rejection of the QAPP along with suggestions on how to modify the QAPP to make it acceptable, provided that the Manufacturer has made a good faith effort to develop an acceptable QAPP (i.e. the QAPP is 75 to 80% acceptable with only minor changes needed to produce an acceptable plan. NSF will not write QAPPs for Manufacturers.

A number of individuals may be responsible for monitoring equipment operating parameters and for sampling and analysis QA/QC throughout the verification testing. Primary responsibility for ensuring that both equipment operation and sampling and analysis activities comply with the QA/QC requirements of the Manufacturer FOD (Section 6) shall rest with the qualified testing organization, with oversight by the NSF. QA/QC activities for the equipment shall include those activities recommended by Manufacturer and those required by the NSF to assure the verification testing will provide data of the necessary quality.

QA/QC activities for the analytical laboratory that analyzes samples sent off-site shall be the responsibility of that analytical laboratory's supervisor. If problems arise or any data appear unusual, they shall be thoroughly documented and corrective actions shall be implemented as specified in this section. The QA/QC measurements made by the off-site analytical laboratory are dependent on the analytical methods being used.

6.3 Data Quality Indicators

The data obtained during the verification testing must be of sound quality for conclusions to be drawn on the equipment. For all measurement and monitoring activities conducted for equipment verification, the NSF and EPA require that data quality parameters be established based on the proposed end uses of the data. Data quality parameters include four indicators of data quality: representativeness, completeness, accuracy, and precision.

Treatment results generated by the equipment must be verifiable for the purposes of this program to be fulfilled. High quality, well documented analytical laboratory results are essential for meeting the purpose and objectives of this verification testing. Therefore, the following indicators of data quality shall be closely evaluated to determine the performance of the equipment when measured against data generated by the analytical laboratory.

6.3.1 Representativeness

Representativeness refers to the degree to which the data accurately and precisely represent

the conditions or characteristics of the parameter represented by the data. In this verification testing, representativeness will be ensured by executing consistent sample collection procedures, including sample locations, timing of sample collection, sampling procedures, sample preservation, sample packaging, sample shipping, and sample equipment decontamination (Section 5). Representativeness also will be ensured by using each method at its optimum capability to provide results that represent the most accurate and precise measurement it is capable of achieving.

For equipment operating data, representativeness entails collecting a sufficient quantity of data during operation to be able to detect a change in operations. For nitrate treatment processes detecting a +/- 10 percent change in an operating parameter (e.g. headloss) is sufficient. Flow rates shall also be known within +/- 10 percent.

6.3.2 Completeness

Completeness refers to the amount of data collected from a measurement process compared to the amount that was expected to be obtained. For this verification testing, completeness refers to the proportion of valid, acceptable data generated using each method. The completeness objective for data generated during this verification testing is 85 percent.

6.3.3 Accuracy

For water quality analyses, accuracy refers to the difference between a sample result and the reference or true value for the sample. Loss of accuracy can be caused by such processes as errors in standards preparation, equipment calibrations, loss of target analyte in the extraction process, interferences, and systematic or carryover contamination from one sample to the next.

For equipment operating parameters, accuracy refers to the difference between the reported operating condition and the actual operating condition. For water flow, accuracy is the difference between the reported flow indicated by a flow meter and the flow as actually measured on the basis of known volumes of water and carefully defined times (bucket and stopwatch technique) as practiced in hydraulics laboratories or water meter calibration shops. For mixing equipment, accuracy is the difference between an electronic readout for equipment RPMs and the actual measurement based on counted revolutions and measured time. Accuracy of head loss measurement can be determined by using measuring tapes to check the calibration of piezometers for gravity filters or by checking the calibration of pressure gauges for pressure filters. Meters and gauges must be checked periodically for accuracy, and when proven to be dependable over time, the time interval between accuracy checks can be increased.

6.3.4 Precision

Precision refers to the degree of mutual agreement among individual measurements and provides an estimate of random error.

6.4 Quality Control Checks

This section describes the QC requirements that apply to both the treatment equipment and the on-site water quality analyses. It also contains a discussion of the corrective action to be taken if the QC parameters fall outside of the evaluation criteria.

The quality control checks provide a means of measuring the quality of data produced. The Manufacturer may not need to use all the ones identified in this section. The selection of the appropriate quality control checks depends on the equipment, the experimental design and the performance goals. The selection of quality control checks shall be based on discussions among the Manufacturer and the NSF. Some types of quality control checks applicable to operating water treatment equipment were described in Section 6.3.4.

6.4.1 Quality Control for Equipment Operation

This section will explain the methods to be used to check on the accuracy of equipment operating parameters and the frequency with which these quality control checks shall be made. A key aspect of the Equipment Verification Testing Program is to provide operating results that will be widely accepted by state regulatory engineers. If the quality of the equipment operating data can not be verified, then the water quality analytical results may be of no value. Because water can not be treated if equipment is not operating, obtaining valid equipment operating data is a prime concern for verification testing.

An example of the need for QC for equipment operations is an incident of state rejection of test data because the treatment equipment had no flow meter to use for determining engineering and operating parameters related to flow.

6.4.2 Water Quality Data

After treatment equipment is being operated and water is being treated, the results of the treatment are interpreted in terms of water quality. Therefore the quality of water sample analytical results is just as important as the quality of the equipment operating data. Most QA plans emphasize analytical QA. The important aspects of sampling and analytical QA are given below:

6.4.2.1 **Duplicate Samples**: Duplicate samples must be analyzed to determine the precision of analysis. The procedure for determining samples to be analyzed in duplicate shall be provided with the frequency of analysis and the approximate number.

6.4.2.2 **Method Blanks**: Method blanks are used to evaluate analytical method-induced contamination, which may cause false positive results.

6.4.2.3 **Spiked Samples**: The use of spiked samples will depend on the

testing program, and the contaminants to be removed. If spiked samples are to be used specify the procedure, frequency, acceptance criteria, and actions if criteria are not met.

6.4.2.4 **Travel Blanks**: Travel blanks shall be provided to the analytical laboratory to evaluate travel-related contamination.

6.4.2.5 **Performance Evaluation Samples for On-Site Water Quality Testing**: Performance evaluation (PE) samples are samples whose composition is unknown to the analyst that are used to evaluate analytical performance. Analysis of PE samples shall be conducted before pilot testing is initiated. PE samples shall be submitted by the field testing organization to the analytical laboratory and also to the equipment testing organizations if appropriate. The control limits for the PE samples shall be used to evaluate the equipment testing organization's and analytical laboratory's method performance. One kind of PE sample that would be used for on-site QA in most studies done under this protocol would be a turbidity PE sample.

PE samples come with statistics about each sample which have been derived from the analysis of the sample by a number of laboratories using EPA-approved methods. These statistics include a true value of the PE sample, a mean of the laboratory results obtained from the analysis of the PE sample, and an acceptance range for sample values. The analytical laboratory is expected to provide results from the analysis of the PE samples that meet the performance objectives of the verification testing.

6.5 Data Reduction, Validation, and Reporting

To maintain good data quality, specific procedures shall be followed duringdata reduction, validation, and reporting. These procedures are detailed below.

6.5.1 Data Reduction

Data reduction refers to the process of converting the raw results from the equipment into concentration or other data in a form to be used in the comparison. The procedures to be used will be equipment dependent. The purpose of this step is to provide data which shall be used to verify the statement of performance capabilities. These data shall be obtained from logbooks, instrument outputs, and computer outputs as appropriate.

6.5.2 Data Validation

The operator shall verify the completeness of the appropriate data forms and the completeness and correctness of data acquisition and reduction. The field team supervisor or another

technical person shall review calculations and inspect laboratory logbooks and data sheets to verify accuracy, completeness. Calibration and QC data shall be examined by the individual operators and the laboratory supervisor. Laboratory and project managers shall verify that all instrument systems are in control and that QA objectives for accuracy, completeness, and method detection limits have been met.

Analytical outlier data are defined as those QC data lying outside a specific QC objective window for precision and accuracy for a given analytical method. Should QC data be outside of control limits, the analytical laboratory or field team supervisor shall investigate the cause of the problem. If the problem involves an analytical problem, the sample shall be reanalyzed. If the problem can be attributed to the sample matrix, the result shall be flagged with a data qualifier. This data qualifier shall be included and explained in the final analytical report.

6.5.3 Data Reporting

This section contains a list of the water quality and equipment operation data to be reported. At a minimum, the data tabulation shall list the results for feed water and treated water quality analyses and equipment operating data. All QC information such as calibrations, blanks and reference samples are to be included in an appendix. All raw analytical data shall also be reported in an appendix. All data shall be reported in hard copy and electronically in a common spreadsheet or database format.

6.6 Calculation of Data Quality Indicators

The equations for any data quality indicator calculations employed shall be provided. These include: precision, relative percent deviation, standard deviation, accuracy, and completeness.

6.7 System Audits

On-site system audits for sampling activities, field operations, and laboratories shall be conducted as specified by the NSF Equipment Verification Testing Plan. These audits willbe performed by the NSF to determine if the NSF Equipment Verification Testing Plan is being implemented as intended Separate audit reports will be completed after the audits and provided to the participating parties through the NSF.

6.8 Reports

6.8.1 Status Reports

The equipment testing organization shall prepare periodic reports for the NSF project managers. These reports shall discuss project progress, problems and associated corrective actions, and future scheduled activities associated with the verification testing. When problems occur, the Manufacturer and equipment testing organization project managers shall discuss them with the NSF technical lead, estimate the type and degree of impact, and describe the corrective actions taken to mitigate the impact and to prevent a recurrence of the

problems. The frequency, format, and content of these reports shall be outlined in the Manufacturer FOD.

6.8.2 Audit Reports

Any QA audits or inspections that take place in the field or at the analytical laboratory while the verification testing is being conducted shall be formally reported by the equipment testing organizations to the NSF project manager who will forward them to the Manufacturer and NSF QC Manager for appropriate actions.

6.9 Corrective Action

Each Manufacturer FOD must incorporate a corrective action plan. This plan must include the predetermined acceptance limits, the corrective action to be initiated whenever such acceptance criteria are not met, and the names of the individuals responsible for implementation.
Routine corrective action may result from common monitoring activities, such as:

- Performance evaluation audits
- Technical systems audits

Content of Manufacturer Field Operations Document Regarding Quality Assurance Project Plan:

The Manufacturer shall be responsible for including the following elements in the Manufacture r FOD:

- *Description of methodology for measurement of accuracy.*
- *Description of methodology for measurement of precision.*
- *Description of the methodology for use of b lanks, the materials used, the frequency, the criteria for acceptable method blanks and the actions if criteria are not met.*
- *Description of any specific pro cedures appropriate to the analysis of the PE samples. It has to be clear how these samples are going to be used in the verification testing. One use of PE samples is in the conduct of a performance audit (see Section 6.7.1).*
- *Outline of the procedure for determining samples to be a nalyzed in duplicate, the frequency and approximate number.*
- *Description of the procedures used to assure that the data are correct.*
- *Listing of equations used for any necessary data quality indicator calculations. These include: precision, relative percent deviation, standard deviation, accuracy, and completeness.*
- *Outline of the frequency, format, and content of reports in the Manufacturer FOD.*
- *Development of a corrective action plan in the Manufacturer FOD.*

Manufacturer Responsibilities:

- *Provision of all QC information such as calibrations, blanks and reference samples in a n appendix. All raw analytical data shall also be reported in an appendix.*
- *Provision of all data in hard copy and electronic form in a common spreadsheet or databas e format.*

7.0 DATA MANAGEMENT AND ANALYSIS, AND REPORTING

7.1 Data Management and Analysis

The Manufacturer, the qualified testing organization and the NSF each have distinct responsibilities for managing and analyzing verification testing data. The equipment testing organization is responsible for managing all the data and information generated during the verification testing. The Manufacturer is responsible for furnishing those records generated by the equipment testing organization. The NSF will be responsible for analysis and verification of the data

A variety of data may be generated during a verification testing. Each piece of data or information identified for collection in the NSF Equipment Verification Testing Plan shall be provided to the NSF. The data management section of the Manufacturer FOD shall describe what types of data and information needs to be collected and managed. It shall also describe how the data shall be reported to the NSF for evaluation.

Laboratory Analyses: The raw data and the validated data must be provided to the NSF. These data shall be provided in hard copy and in electronic format. As with the data generated by the innovative equipment, the electronic copy of the laboratory data shall be provided in a spreadsheet, and a data dictionary shall be provided. In addition to the sample results, all QA/QC summary forms must be provided.

Other items that must be provided include:

- field notebooks;
- photographs, slides and videotapes (copies);
- results from the use of other field analytical methods;

7.2 Report of Equipment Testing

The qualified testing organization shall prepare a draft report describing the verification testing that was carried out and the results of that testing. This report shall include the following topics:

- Introduction
- Executive Summary
- Description and Identification of Product Tested
- Procedures and Methods Used in Testing
- Results and Discussion
- Conclusions and Recommendations
- References
- Appendices
- Manufacturer FOD
- QA/AC Results

The NSF will review the draft report, the results of testing, the QA/QC results, and will preparea final report.

Content of Manufacturer Field Operations Document Regarding Data Management and Analysis, and Reporting:

The Manufacturer shall be responsible for including the following elements in the Manufacture r FOD:

- *Description of what types of data and information needs to be collected and managed.*
- *Description of how the data will be reported to the NSF for evaluation.*

8.0 SAFETY MEASURES

The safety procedures shall address safety considerations which relate to the health and safety of personnel required to work on the site of the test equipment and persons visiting the site. Many of these items will be covered by site inspections and construction and operating permits issued by responsible agencies. They will include:

- regulations covering the storage and transport of chemicals.
- conformance with the National Electric Code.
- provision of parking facilities, sanitary facilities.
- provision of and access to fire extinguishers.
- regulations covering site security.
- conformance to any building permit requirement such as provision of handicap access or other health and safety requirements.
- ventilation and air conditioning of equipment or of trailers or buildings housing equipment, if gases generated by the equipment could present a safety hazard.

Content of Manufacturer Field Operations Document Regarding Safety:

The Manufacturer FOD shall addre ss safety considerations that are appropriate for the equipment being tested, if any, being used in the verification testing.